NASA Facts

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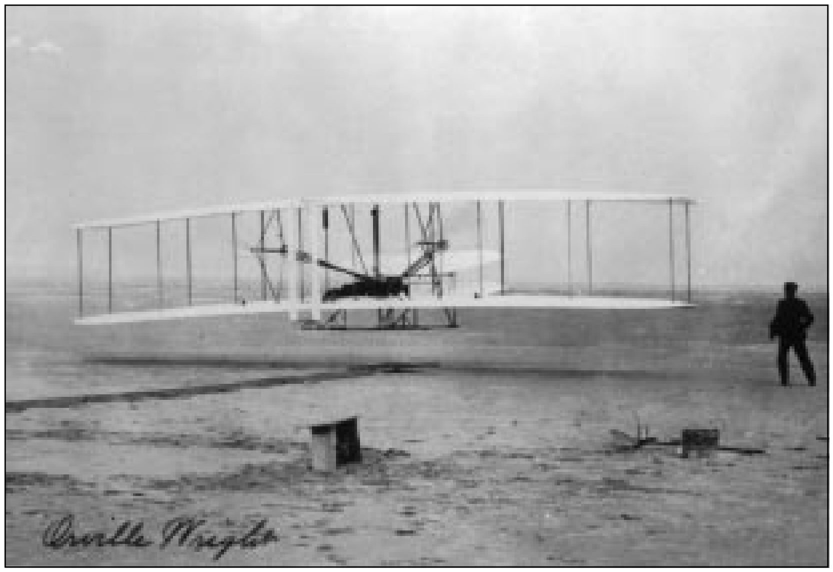
Flight Research

What Is "Flight Research?"

In 1901, Wilbur Wright argued that to really learn about flight, one had to "mount a machine and become acquainted with its tricks by actual trial." That argument still holds true today in the unique discipline of flight research, the specialty of NASA's Dryden Flight Research Center, Edwards, Calif. In flight research, new aeronautical concepts and new aircraft designs are flown and tested using actual aircraft. In other words, flight research is that point where the rubber meets the road, where the aircraft, human and real-life flight conditions come together for the first time. It provides technology with a moment of truth, where theory and reality come face to face; where its participants "separate the real from the imagined," as Hugh L. Dryden, former NASA Deputy Administrator and NASA Dryden's namesake, once said.



First flight of a piloted aircraft, Dec. 17, 1903, with Orville Wright at the controls. *Photo courtesy of the Library of Congress*

Origins of Flight Research

The unknown is inherently unpredictable. Wind tunnels, simulators and computers can only model what is known. That became clear by the mid-1940s as engineers began to probe the technological challenges of piloted, supersonic flight. Data from transonic wind tunnels was inconclusive, and the practice of near-supersonic dives in production aircraft was too dangerous. It became apparent that to push the boundaries of knowledge, to see what lay beyond the current frontier, someone actually had to go there. It was clearly the time for specially built, experimental airplanes.

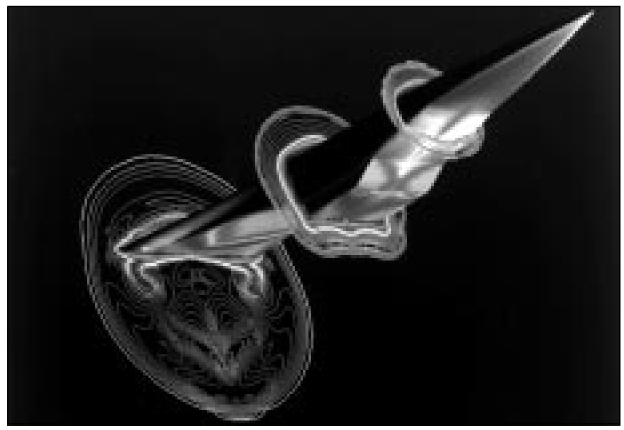
The National Advisory Committee for Aeronautics (NACA), the prime United States government agency responsible for aeronautical research, began work with the armed services to develop the first research airplanes capable of supersonic flight. By early 1945 the world's first experimental airplanes were under development: the rocket-powered XS-1 (later designated X-1), built under Army sponsorship by Bell Aircraft, and the turbojet-powered D-558-1 constructed by Douglas Aircraft under Navy patronage. The XS-1 broke the sound barrier on Oct. 14, 1947, and a later version of the D-558-1 (the D-558-2) became to first aircraft to fly faster than twice the speed of sound.

The research techniques pioneered during those early programs were perhaps even more important than the airplanes' achievements. The XS-1s, for example, carried extensive quantities of NACA-supplied instrumentation, which allowed engineers to collect comprehensive data in the transonic region. Such aeronautical information resulted in a total of 90 NACA reports about the X-1 family. Data from these reports provided the basis for subsequent transonic and supersonic aircraft and helped lay the foundation for America's conquest of space. Thus the XS-1 program helped pioneer the process of discovery through flight research.

The Tools of Aeronautical Research

Flight research is one of the four basic tools of aeronautical research. The other three —computational fluid dynamics (CFD), wind tunnels and ground-based flight simulators — are used in cooperation with flight research to help engineers understand the performance of the flight vehicle. Flight research represents the final step in any research program though.

Aerodynamic forces are predicted through computational fluid dynamics, or "analysis." Simply put, it is the process of computing what a molecule of air does as it moves from the nose to the tail of the aircraft; if done for enough molecules, it can forecast the total flow patterns and forces around the aircraft.



Computational fluid dynamics model of a scramjet engine and exhaust. *NASA Langley photo L-91-16133*

NASA's 30- by 60-foot wind tunnel. *NASA Langley photo L-92-12858*

Wind tunnels provide a means to test accurate scale models and full-sized aircraft, over some of the normal speed range encountered in flight. These are carefully controlled tests, using a calibrated airstream rushing past a model or an aircraft mounted in the tunnel. Accurate balances measure the forces, and computers translate those measurements of pounds of tension and compression into coefficients of lift, drag and pitching moments. Lift is the aerodynamic force that supports an aircraft in flight, due to the airflow over the wings or body. Drag is the resistance a vehicle moving through the air experiences, and pitching moments are a result of aerodynamic forces that make the nose of an aircraft move either up or down.

The simulator offers a third approach to research. Driven by computers that calculate the behavior of an aircraft and present it in a display, the simulator provides a way to "fly" an aircraft before it is built. The characteristics of the vehicle, determined from drawings, analysis and model tests, are programmed into the computer. As pilots and engineers fly the new design, its good and bad qualities are revealed. The simulator also can be used to duplicate an existing aircraft's flying qualities and to present dangerous flight situations in a safe environment for crew training. It can refine an airplane design before final production drawings are released. It also helps to study the effects of minor or major changes in the aircraft's components, powerplant or other systems.

Dryden's X-33 Advanced Technology Demonstrator flight simulator. *NASA photo EC97 44008-2*

After research has been performed using the other three tools, one step remains: flight of the vehicle itself. NASA research pilots, who also are engineers, conduct a meticulous program that gradually probes an aircraft's envelope (capabilities), edging toward the speed, altitude and load limits that will define the final performance of an aircraft or concept. This full-scale research furnishes answers that will verify, extend and perhaps correct the inputs from analysis, wind-tunnel tests and simulation. It is the final, essential step in the development process.

Experimental Research Aircraft

Flight research involves doing precision maneuvers in either a specially built experimental aircraft or an existing production airplane that has been modified. Research aircraft are the tools for exploration and discovery. Each is instrumented to acquire data about the aircraft, its systems and even the surrounding environment during research flights. Originally, they often were called "flying laboratories."

Until the 1970s, experimental planes (designated "X"-planes for "experimental") were the chief research tools simply because research at Dryden probed flight regimes that wind tunnels, simulators and production aircraft could not approach. For example, before the XS-1 broke the "sound barrier" in 1947, there was no proof that the best available supersonic wind-tunnel data was reliable. The vast amounts of data that the X-1s and other early research airplanes obtained were important for validating the new wind tunnels (particularly the ventilated-throat transonic tunnels) under development at the time. One of the greatest benefits was intangible; the confidence gained at the time by the achievement of safe, controllable supersonic flight.

The X-15s of the 1950s and 1960s helped verify theories and wind-tunnel predictions concerning hypersonic flight (at speeds greater than Mach 5). The X-15 program collected data that contributed to more than 750 research papers and reports. It had real-life applications as well, like the practical, fullpressure flight suit for pilot protection in space, the first large, restartable, throttleable rocket engine and the first reusable aircraft structure capable of withstanding the temperatures of hypersonic reentry into the atmosphere. The program also illuminated discoveries about hypersonic aerodynamic heating that were not predicted by other methods. Like the 1940s supersonic research, the X-15 program gathered unique data, and it expanded the human experience -- this time successfully taking piloted flight to the edge of space.

The X-15 was an experimental research aircraft used for flight research at Dryden from 1959-1968. *NASA photo EC67 1731*

The F-15B is a production aircraft used for flight research at Dryden today. *NASA photo EC96 43546-1*

Production Aircraft as Research Vehicles

Modified production aircraft have been used for flight research at Dryden since the 1950s. In the early 1970s they became the primary tools for research as it became focused on more specific concepts within the envelopes of existing aircraft. New airfoil designs, research engines and new flight-control systems were used on aircraft ranging from gliders to jet transports and fighters during programs verifying a variety of aeronautical concepts and technologies.

The NASA F-8 Digital-Fly-By-Wire (DFBW) is an example of a conventional aircraft that became an important research vehicle. It was a former Navy fighter, modified in the early 1970s so it could be flown with computer-driven, electronic flight controls instead of the mechanical types that were common on all aircraft at the time. It was the forerunner of the fly-by-wire flight control systems that are now the norm on space vehicles, the latest airliners and virtually all new fighter aircraft. Its use on the X-29 proved that even an extremely unstable aircraft could be flown with superior reliability.

More recently, Dryden used two F-16s with modified wings, called F-16XLs, to investigate laminar (smooth) flow. Laminar flow pertains to the airflow above and below a wing. Perfectly laminar flow increases the efficiency of a wing, but has been nearly impossible to achieve at high speeds. The F-16XL program was the first study of laminar flow over highly swept wings at supersonic speeds. The F-16XL's wing incorporated an experimental device called a "glove." The glove was designed to both gather information about airflow over the wings and to achieve laminar flow by drawing off turbulent air through millions of perforations in its surface. Laminar flow research could result in greater fuel savings for all future high-speed aircraft, including the next generation supersonic airliner such as the proposed High Speed Civil Transport.